

# Aerial Platforms for Venus Exploration

International Planetary Probe  
Workshop IPPW 14

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# Topics



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  - Atmosphere
  - Surface and Interior
  - Surface Atmosphere Interaction
  - Summary
- Flight Opportunities
  - Venus Bridge
  - Venera D
  - Venus Flagship
- Technology – Preliminary Assessment
- Roadmap – Preliminary Assessment
- Issues to be worked prior to Study Team Meeting 2



# Introduction



- The dense atmosphere of Venus and severe surface temperatures have precluded in situ exploration with the lander and rover technologies that have been successfully deployed at Mars
- Atmospheric platforms are a promising alternative with promise for studying the atmosphere, surface and interior and the interactions between them
- NASA's Planetary Science Division has initiated a study with the goal of developing a roadmap for the exploration of Venus with aerial platforms and to define the key technology that will be needed
- The first face to face meeting of the study team was held in Pasadena from May 30 to June 2, 2017 and was focused on identifying the key scientific objectives for aerial platforms at Venus and to consider future flight opportunities
- This is a status report on the study which will be completed in January 2018

Predecisional information for planning and discussion only

## Atmosphere

- How did the atmosphere form and evolve?
- What controls the atmospheric super-rotation and greenhouse?
- What is the impact of clouds on climate and habitability?

## Surface & Interior

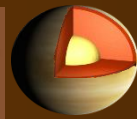
- How is heat released from the interior and has the global geodynamic style changed with time?
- What are the contemporary rates of volcanism and tectonism?
- How did Venus differentiate and evolve over time?

## System Interactions & Water

- Was surface water ever present?
- What role has the greenhouse had on climate history?
- How have the interior, surface, and atmosphere interacted as a coupled system over time?



# Platform Concepts Considered in this study



## Mid-Upper Atmosphere Vehicles

- Constant Altitude Balloons
- Altitude Control Balloons
- Hybrid Vehicles
- Solar Airplanes

## Deep Atmosphere Vehicles

- Venus Geoscience Aerobot
- Venus Mobile Explorer
- Sample Return Dual Balloon
- Probes and Sondes

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- Altitude control makes it possible to characterize and understand the atmospheric super-rotation and global circulation, by measuring the zonal and meridional wind structure over the range of accessible altitudes
- Altitude control provides a unique opportunity to probe below the lower cloud deck to haze layer to a region where heating rates is not accounted for by current models
  - Measure temperature profile, haze optical properties below clouds and wave activity.
  - If practical make precise measurements of net flux to constrain heating rates to improve circulation model.
- Altitude control can make it possible to characterize the Hadley cell structure.
  - Primary observables are position and velocity
  - Important scientifically and for designing trajectories to optimize mission life
- Altitude control can also enable exploration of the UV absorbing layer.
  - Key observables are particle size and composition as a function of altitude.
  - Need to define what is the minimum altitude range that will do the job
- Probe measurements of the deep atmosphere are needed
  - To confirm nitrogen deficiency within 7 km of the surface
  - To investigate any other departures from uniform mixing
  - To understand forces exerted on the planetary surface by the atmosphere

Predecisional information for planning and discussion only



# Science - Surface and Interior



- Substantial geophysics-related science feasible from aerial platform operating in regions of benign temperatures.
  - Huge improvement in quality of data by being closer to surface (i.e. below orbit);
  - Performance gain achievable with still lower altitude.
  - Magnetic field, Schumann resonance, and gravity are of interest
- Measurements of atmospheric pressure and frictional forces on Venus combined with radar measurements of variations in the length of the day may provide the means of determining the M of I and hence the deep structure of Venus (II.A.2)<sup>1</sup>
- Visible imaging of surface is of interest, but requirements need clarification
  - Need platform within 106 km of the surface
  - IR will be challenging at low altitudes because of the temperatures
- Potential for infrasound-based detection of seismic activity
  - Can detect seismic activity at a low level
  - Need to understand ability to probe interior from aerial platform measurements

1. Designation refers to [VEXAG Goals Objectives and Investigations for Venus](#)

- Access to lowest part of the atmosphere with probes, sondes or other very low altitude aerial platforms can enable key GOI objectives
  - Identification and characterization of any areas that reflect formation in a geological or climatological environment significantly different from present day
  - Current rate of sulfur outgassing from the surface
- Objectives in the GOI requiring measurement of noble gases and stable isotope ratios in the atmosphere are feasible
  - Long integration times could permit greater precision
  - Altitude control could enable test of whether ratios are altitude independent
- Geophysical investigations of interior-surface- atmosphere interaction (II.B.5) can help understand the mechanisms controlling the superrotation, Venus rotation and Venus interior structure.
  - Understanding atmospheric torques on the planet pressure and frictional. Including observations of the bow wave in situ and its time of day dependence?
  - Couple this with radar measurements of Venus rotation rate variation from Earth or orbit



- The importance of altitude control is a strong common thread running through all three science areas.
- Horizontal position control does not appear to be as critical
  - Altitude control will enable moving in and out of different airmasses
  - Fine positional control not a high priority at this time
  - Adequate positional knowledge both desirable and achievable
  - Positional control sufficient to overcome meridional drift would be desirable
- Probes that can enter and operate in the lower 10 km of the atmosphere are also a priority
  - Short life time probes can carry out the most complex measurements
  - Long lived probes will require development but sensors will be limited in what they can measure to pressure, temperature, acceleration etc.

- Three potential strategic flight opportunities have been identified for Venus Aerial Platforms. These are concepts for directed missions or programs whose focus is exclusively on Venus
  - Venus Bridge
  - Venera D
  - Venus Flagship Mission
- There are other opportunities in competed programs
  - Discovery - there have been several Venus aerial platform proposals in the past
  - New Frontiers – The NF 2 solicitation specifically called for a low altitude aerial platform but this was later deemed to be too immature technologically for NF



# Flight Opportunities: Venus Bridge Concept



- Venus Bridge
  - NASA's Science Mission Directorate Associate Administrator has initiated an investigation of whether Venus exploration is feasible within a \$200M cost cap
  - The VEXAG Venus Bridge Focus Group has determined that low cost aerial platforms should be considered as candidate Venus Bridge mission. Technology needs to be quite mature to be considered
- Venus Aerial Platforms Study Team - Preliminary Findings.
  - Five concepts of varying degrees of technical difficulty were looked at by Venus Bridge Focus Group. Two other concepts were identified here
  - Several small simple balloons with minimal payloads floating at different altitudes and tracked in order to study atmospheric circulation
    - Other measurements might be pressure, temperature and solar flux (down and up)
    - Also determine IR fluxes at altitudes where temperature allows.
    - One entry shell is likely to be the most affordable. An alternative is to shoot for three providing an option to descope.
  - Solar airplane as presented at this workshop by Geoffrey Landis.
    - Technology is quite mature



# Flight Opportunities: Venera D Concept



- Venera D and Venera D Joint Science Definition Team (JSDT)
  - This is a Russian mission concept with a nominal launch in 2025 and a lander and an orbiter constituting the baseline mission
  - The US- Russia JSDT has identified observations in the atmosphere and aerial mobility as particularly important. The concept for a long-lived in situ surface explorer (LISSE) is also of interest.
- Venus Aerial Platforms Study Team- Preliminary Findings
  - Variable altitude is very interesting scientifically, but even a constant altitude balloon will take some development effort.
  - Small superpressure balloons and uncontrolled variable altitude balloons may be pretty close to readiness.
  - JSDT has a limited timeframe in which to deliver its next report. Need to start working mission architecture issues, so need to downselect options soon.
  - No clear guidance from NASA on the resources available for additional mission elements. An instrument may be an alternative to another mission element.
  - Venera D may be a good opportunity for tech demos.



# Flight Opportunities: Venus Flagship Mission



- Prior Concepts
  - [Venus Flagship Mission](#) studied in 2009 included two superpressure constant altitude balloons
  - [Venus Climate Mission](#) – A flagship mission studied for the Planetary Science Decadal Survey in 2010 included a single constant altitude superpressure balloon, a probe and two sondes
- Venus Aerial Platforms Study team - Preliminary Findings
  - Variable altitude platform addresses both atmosphere and surface science. Might improve ability to do IR observations by cooling instruments at higher altitude between dips to lower altitude.
  - Up and down on command increases science over uncontrolled altitude variation. Positional knowledge and control are distinct issues; both are required
  - Adding probes and sondes adds a lot of science.
    - Expect to be able to do more than in previous flagship studies.
    - Non-zero L/D might extend descent time even without guidance.
    - Gliding in direction of balloon might improve communications relay performance. Benefits to imaging more terrain. However, no GOI requirement for this.

- Technology Needs
  - Not the primary purpose of this meeting but need to identify key areas to ensure we have the right expertise for the next Study Team meeting
  - Emphasize nearer term with focus on Venus Bridge, Venera D, and Flagship
  - Include mid and far term and particularly for disruptive technologies
- Technology expertise needed for the next Study team meeting
  - Solar power for persistent platforms is a cross-cutting item.
    - Altitude dependence of spectrum, flux, solar cell performance. Environmental tolerance
    - Can anything be done on night side with 1 um emission?
  - Batteries
    - For high altitude platforms
    - High temperature batteries
  - Position knowledge, especially on back side of Venus away from Earth
    - Role of cubesats in navigation
  - Low cost entry systems. Ultra lightweight and inflatable decelerators.
  - High temperature electronics
  - Physics and chemistry of Venus environments

- Goal is not to delineate a large range of possible scenarios but to identify issues that will affect the logical development of missions
  - Access to Venus - particularly for Venus Bridge
  - Feedforward issues – science, environment and technology
  - Cadence of good opportunities to get to Venus
  - Infrastructure development – cubesats and smallsats for communications and navigation
  - International collaboration – adoption of communication standards
- Role of technology demonstrations
  - Anticipate instrumenting the thermal protection systems as with recent Mars missions (MEDLI)
  - Should there also be instrumentation to monitor performance of key aerial platform systems in the Venus environment?
  - Is it necessary to characterize effect of atmospheric absorption and refraction as a function of zenith angle on telecom performance for optimizing future missions?



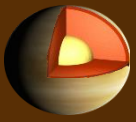
# Issues to be worked prior to Study Team Mtg 2



- Venus rotation rate and surface-atmosphere interaction
  - What can it tell us about Venus?
  - What are the key measurements
- Model trajectory of a balloon with altitude control using GCM
- Basic performance curves for aerial platform options:
  - Payload fraction for variable altitude vehicles
  - Scalability.
- Telecom orbiter:
  - Cost/benefit trade vs DTE (direct-to-Earth)
  - Orbit options
- Data issues
  - What are data requirements of different mission concepts?
  - Given a limited data return capability, what science can be done?
- Imaging performance dependencies
  - Altitude
  - Spectral band
  - Day and night side
- Physics and chemistry of supercritical gas mixtures
  - Explanation for nitrogen deficiency in lower atmosphere



# Other Participants



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